DESIGN AND COST OF HIGHWAY RECONSTRUCTION

BY

O. E. ANDREN
J. D. HARVEY
L. E. STARKEL

ARMOUR INSTITUTE OF TECHNOLOGY

1917

THE DESIGN AND COST OF A HIGHWAY RECONSTRUCTION

A THESIS

PRESENTED BY

JAMES D. HARVEY, LEONARD E. STARKEL
OLOF E. ANDREN

TO THE

PRESIDENT AND FACULTY

OF

ARMOUR INSTITUTE OF TECHNOLOGY

FOR THE DEGREE OF

BACHELOR OF SCIENCE

IN

CIVIL ENGINEERING

MAY 31, 1917

APPROVED:

Alfred E. Phillips
Professor of Civil Engineering

H. M. Raymond
Dean of Engineering Studies

L. C. Monin
Dean of Cultural Studies

[illegible]

[illegible]

[illegible]

[illegible] [illegible]

[illegible]

Methods and Costs of Reconstruction of a Highway

TABLE OF CONTENTS

Methods and Costs of Reconstruction of a Highway

OBJECT

The following thesis comprises a complete analysis of a highway reconstruction,,and the discussion of the conditions which render valuable such an analysis. The section of highway selected for the work lies in Rock County, Wisconsin, on the road between Edgerton and Coo Cooksville. The community is a typically rural one and the almost immpassable condition of the road during rainy season, requires the application of real highway methods.

Methods and Costs of Reconstruction of a Highway

Historians say that Ancient Rome never could have been a great nation but for its splendid roads. We may draw the rapid conclusion from this statement that the prosperity and power of our nation will be accompanied, and in a measure caused, by the developement of our highway system. Railway and water routes will always be the medium of inter-city and inter-state transportation, and these have been developed to a high degree; but the cities and states so connected are insignificant in number compared with the villages and towns which are in some respects, the basic economic units. For these villages and towns, the highway will always be an important problem, and strange to say, our Nation as a whole has been more remiss in developing this important function than the ordinary person realizes. The subject of good roads now seems

to many to be a vexatious proposition requiring over-burdensome taxation and bother, but it has been proved conslusively that money properly invested in road improvements actually yields benefits, socially and economically, to a larger percentage than the ordinary business investment.

The succeeding analysis of a highway reconstruction concerns a rural road burdened with the usual problems and obstacles, and it might be well to point out the need and value of such work; and to give a resumé of Federal, State and County provisions and enactments bearing on it.

When the various ways in which good roads benefit a community are examined, a complex situation is found in which many actions and reactions take place. When good roads

reduce the cost of hauling, adjacent land becomes more valuable; There is a corresponding tendancy for the population to increase, and in its turn, this tendancy strengthens the demands for good roads; social conditions improve; and the life of the community is influenced in numerious ways. It is not always correct to say that good roads are the primary cause of increase in property valuation. It is, however, to conclude that good roads and an increased property valuation are inseparable.

Methods and Costs of Reconstruction of a Highway

There are certain direct financial advantages which follow the improvement of public roads in a community. These advantages are probably more apparent in the reduced cost of hauling. Certain dependent economic advantages also arise from such improvements, for example the increased value of farm lands. It should not be considered, however, in presenting the advantages of improved roads, that the direct cost of hauling and the increase in farm values are entirely sepatate and independent, for the values increase when the costs of hauling decrease.

Whatever methods are used to improve a road, the improvement for hauling purposes is due to three causes: the betterment of the road surface, the grade reduction and the shortening of the length. On such an improved road, the time required to haul a given quantity of

material a given distance is reduced. The reduction may be due largely to increased speed of hauling, to increased load, or both. It is important to recognize that for transportation purposes, reduction of time is equivalent to a decrease to the distance to the market centers. It is very easy to see then, why the increase of farm values must follow improved roads, for the effect is to bring the farms, in a sense, closer to the towns. The fact, that on roads with improved surfaces, hauling becomes largely independent of the season of the year, or weather conditions, means very considerable reductions in hauling costs. It also measn that many of the limitations of the number and kinds of farm operations are immediately removed.

In order to fix one's ideas on the reduction of hauling cost due to road improvement, the transpotation of goods to the railroad and of farm produce to the market should

Methods and Costs of Reconstruction of a Highway

be considered. The present cost of this work in the United States is high, and is due in the main, to steep grades and yielding road surfaces. On any grade, in addition to the tractive forces due to surface conditions, the force of gravity must be overcome. The horse must raise his own weight and, because of the manner in which his strength is applied, it becomes less and less available as the grade increases. For example, if a 1200-pound horse, by exerting a force equal to one-tenth of his weight, can draw a load of about 2000 lbs. on a level earth road; with the same force exerted against his collar he can draw continuously only about 1000 lbs. on a 5 percent grade, and only 750 lbs. on a 10 percent grade. The worst grade on any road tends to limit the load that can pass over the entire road, even though for short pulls the horse's efforts may

be doubled.

While steep grades are detrimental on commen earth roads, they are far more so on an improved road. If it is assumed that a 1200-pound horse by exerting a certain effort, can draw a load of 2000 lbs. on a level earth road, under the same conditions, this same horse can draw a 5000 lb. load continuously on a level macadam road, but on a 5 percent grade it can draw only 1600 lbs., while on a 10 percent grade the load would have been reduced to 950 pounds. It is because the tractive force on a macadam surface is so slight the the grade effect quickly exceeds that resistance.

It becomes immediately apparent, therefore, that, when a road is to be improved by surfacing it, the maximum grade allowed must be low in order to secure the full advantage of

the improvement. Moreover, steep grades are slippery and the maintainance charges are high, so the better the surface is made the more imperative it becomes to secure easy grades.

The cost of hauling farm produce to market is probably increased more by the bad conditions of road surfaces than by excessive grades. It is too frequently the case that at seasons when it is most desireable to use the roads the surfaces are soft and consequently the tractive resistances are excessive and wasteful. On a muddy road the amount of load which an ordinary horse can draw varies from nothing yo a maximum of 800 lbs.; while on a well maintained gravel road, such as is used in the succeeding analysis, the amount would be about 3300 pounds. This means that the same horse could do about four times as much work on a good gravel surface than it could do on a muddy earth road.

Methods and Costs of Reconstruction of a Highway

Applying business methods of cost analysis to the farmers hauling problems, some enlightening figures are revealed. In 1906, the Department of Agriculture deduced an aver- cost per ton-mile of 23 cents, for average hauls of 9 miles, based upon replies received from a large number of rural correspondents.

A few individual instances of actual experiences will be cited. A certain farmer had to haul some material a distance of 23 miles. He found that with a two-horse team he could haul a load of 500 lbs. in three days with a ton-mile cost of $1.56. Later this road was improved with a good gravel surface and the ton-mile cost was reduced to 26 cents. In another case, before improvement, farmers made a certain haul in a day, pulling 2500 lbs. per team. After the improvement of the road, the same teams made the hauls twice a day,

pulling 6000 pouns each. In another case, after some county road surfacing had been completed, farmers hauling wheat from their town to the nearest railroad center, found that the hauling cost had been reduced from 15 to 4 cents per bushel. The South is sadly behind in road improvement. With a hauling cost of $40,000,000 per year for the cotton crop, an expenditure of $2,000,000 for roads would yeild big dividend in the reduction of this enormous cost.

The problem of production is decreased simultaneously with the decrease of hauling expence. Where bad roads prevail the farmers are forced to mow their crops, not when the market is favorable,but when the roads are favorable. Oftentimes when the market is highest, the rural producer finds that he cannot get his produce to market, and when the roads become

passable, the market is so flooded that much of the crop is wasted. In a certain winter when potatoes rose to an exorbitant price, certain farmers with heavy drops were unable to haul to town, and much of their crop rotted.

It is because of the above considerations and others that the improvement of our highways is expected to stem the drift of population toward the cities and to increase the countrie's productions in proportion to its growth.

Methods and Costs of Reconstruction of a Highway

Federal and State Aid work is highly instrumental in the present road improvements. Federal Aid on a practical scale, dates from an enactment of Congress during its 1916 session, by which $85,000,000 was appropriated to be distributed in 5 years among the several states on basises of area, population, and mileage of rural delivery and post-office station routes. State Aid work as practised by the State of Illinois (Illinois being fairly typical) provides for financial aid in the construction of permanent highways connecting centers of trade, to the extent of 50 percent of the cost. Besides this, all engineering and inspection work is provided for by the State. In addition to this the State takes over and maintains the highway thereafter, if the road is of brick, concrete or asphalt; and to pay for half of its maintainance if

the pavement is of gravel, or macadam.

Since the passage of the Good Road Acts, July 1913, Illinois has constructed 400 miles of highway under State supervision. All such work has been accomplished according to the State specifications, and the general routes have been determined by it. This ruling is necessary if permanent traffic routes are to be built, and its nees is attested when it is considered that the State of New York in the expenditure of $250,000,000 for roads, wasted a shameful percentage due to mistakes and hit-or-miss methods.

During the years 1916 to 1921 incl., the State of Illinois will receive $3,300,000 from the Federal government provided, however, the State appropriates a like amount. As there is no doubt but what the State will supply

the required amount, the prospect for the near-future looks very bright. The growth of the highway may well be attested when it is considered that the amounts expended in 1916 in Illinois were four times those expended in 1904. That such investments of money are the key to progress is ahown in the comparison of our own State with that of Arkansas and South Carolina, which have actually fallen behind in their mileage of good roads and as a consequence have fallen behind the other states in growth and population and proposerity.

There can be no real preparedness for war, for defence, or for peace, without real highways; and when every corner of our country is interconnected by comprehensive, permanent and well maintained systems, the effect will be apparent in prosperity and ecomomic welfare.

Methods and Costs of Reconstruction of a Highway

The road taken as an example is on the direct route between Edgerton and Cooksville, Rock County, Wisconsin. Our section begins at the termination of the section already improved, and is about five miles out of Edgerton.

In Rock County gravel is in abundamce, and consequently all of the improved roads are constructed of this material. The section of road improved, immediately ahead of our section, is a two-course gravel road nine feet wide with five-foot earth shoulders. After two years of service, this road has few ruts and nothing has been spent as yet on its maintainence.

Gravel for this road was obtained from a gravel pit located two miles from station 0 of our section. A royalty of $.10

per cubic yard was paid to the owner of the property from which the gravel was extracted. A standard gravel grader, the product of the "Good Roads Machinery Co.", is located at this pit. An endless-chain bucket-belt elevates the gravel to the screens and thence to the elevated hoppers. By this scheme the gravel may be dumped directly into the wagons for hauling to the job. The complete cost of gravel at the the bins is $.25 per cubic yard. The gravel from this outfit is furnished by the County to the contractor at the above price, F.O.B. the plant. This outfit is available for use on the section of road considered by us, and the costs of the road metal are calculated from the above figures.

The survey of a road for the consideration of reconstruction consists of tran-

sit line, profile and cross-sections. Stakes are set at every hundred feet, or at intermediate points when necessary; and the distances of their location from the transit line are noted. They are usually placed at the fence line. Elevation of the top of each stake is noted and used for future reference.

Our stretch of road had been surveyed the previous autumn and the stakes were in place for the most part. In running the transit line the approximate center between fences was taken at each perceptible change in direction of the road; and straight lines between these successive points were considered as center-lines of the proposed improvement. The azimuth of each new direction was noted, in order to determine the different bearings of the road, and the interior angles at the intersection points. Distances to stakes, fences, etc., were noted

and the pluses of the various existing culverts, private entrances, houses, barns, etc., were taken in relation to their position with the existing stakes. The stations were not chained, due to the fact that these satkes from the previous survey were in place.

The profile was run down the center line of the road, picking up from an assumed bench mark located on the culvert at station 2 plus 50. The elevation of this B.M. was taken as 100.00. Elevations were taken at every hundred feet and at intermediate points when nedessary. The elevation of the inlets and outlets of the existing culverts were noted. Center-line elevations of private entrances were taken in order not to place the new grade line in such a position as to ultimately be objectionable to the property owner.

Methods and Costs of Reconstruction of a Highway

Cross-sections were taken at every station and at private entrances. No bench marks, or turning points were used in taking the sections, as only the difference in elevations of the prominent points of the several sections were needed. The first reading taken in sectioning was at the center of the road; then the readings of the changes in topography to the right and thence to the left of the center line were noted. Such sections were generally taken as far out as the fence lines on each side and farther out where deemed advisable.

The method of running each phase of the survey separately, was chosen by us to be the most efficent method for a party of three men to employ. The length of road included in this survey extends one hundred and four stations. In this stretch of road, practically every road problem known, was encountered.

Methods and Costs of Reconstruction of a Highway

Between stations 30 and 42 plus 50, the bottoms of the Yahara River were crossed. The river overflows these bottoms and the road to a considerable depth every Spring. It is impassable, even to horse back, during these flood periods. The high water elevation, relative to the piers of the bridge was obtained from the County Superintendant of Rock County. To allow of continuous traffic during these freshets, we propose that the section of road that is innundated be provede with a specially designed concrete spillway, or ford. To the wets end of the bottoms, a steel bridge of a hundred foot span, which crosses the channel of the river, is in place. This bridge, we propose to raise in order that it will clear the flood level during the freshet overflow At the east end of the bottoms, the existing grade is somewhat over twelve percent, while

the upgrade from the bridge floor west is about nine percent.

The material encountered, for the most part, is heavy soil, or muck. This material becomes practically bottomless when the frost leaves the ground in the Spring of the year, as we discovered by experience.

The plans included herein, were plotted from the survey notes. The scale of the transit line is 1 in. equals 80 ft.; and that of the profile is 1 in. equals 80 ft., horizontally , and 1 in. equals 8 ft.,vertically. The ratio of 1 to 10 of the scales of the profile was so taken as to make the variations of the ground visible. The scales used on the cross-sections are both 1 in. equals 8 ft.

A standard road template is used to plot the new road section on the section of the

ground line. This template includes the finished earth portion, or sub-grade of the proposed improvement. Of course, the ditches and the trenches wherein the road metal is placed, are shown on this template. As the grade line on the profile is that of the center-line of the finished improved road, a projection of the template material extends to the level of that finished surface. By means of such, the correct position of the new section is located very easily on the ground section through the elevation taken from the grade line. That is, it is unnecessary to take any separate measurements in plotting. The material of the template was of heavy bristol board.

The typical cross-section of this road consists of a two-course gravel roadway, having a total thickness of seven inches and a width of eight feet. There are six foot

earth shoulders on each side of the gravel pavement. The crown of the road section is sloped from the center to the edge of the earth shoulders with a gradient of 1 in 12. Generally the depth of the ditches below the center of the proposed improvement is twenty-two inches; and the slope of the side wall is 3 to 1. The fill section differs from this, inasmuch as the slope from the edge of the earth shoulders is 1 to 1. At the peaks of the grade lines the ditches are omitted for about three, or four hundred feet on each side of the point of intersection. Refer to section #A1 for fill, and #A2 for cut sections. All demensions are included therein. These are to be found on sheet No. 1 of the plan and profile.

For the special spillway section, a concrete roadway, eighteen feet wide, with rip-rap pavement on each side is proposed.

Methods and Costs of Reconstruction of a Highway

The concrete is to be laid in a single course, six inches in depth, with a crown having a slope of 1/2 in 12 for the middle half of the pavement, and that of 1 in 12 for the two outside quarters of the section. The rip-rap pavement has a slope of 1 in 4 and is to be extended about six feet on each side of the concrete. The under drainage is taken care of by 4" drain tiles running longitudinally on both sides of the center,and at a distance of eight feet from it. This tiling has a gradient of 1%, and is so arranged as to have the low points midway between stations. The drainage of the longitudinal tile is by means of cross-tiles placed at each station. The tiling to the left side of the road has an elevation of 3" less than that to the right of the road, in order to proveide a gradient for the cross-tile. The average depth of the tile is about two feet below the center

of the finished surface of the concrete road.

Preliminary to the determination of the grade line, the template was placed on the road section in such a manner, so that the cut would balance the fill for that section, and the resultant of the finished surface was then noted. These elevations were plotted on the profile and the grade line established by closely approximating these points. However, the elevations of some stations are predetermined by private entrances, culvert clearances, etc.; and the grade of the road had to be kept to 8%, or thereabouts, which caused excessive cuts in places. The advance upgrade is known as plus and the downgrade as minus. Vertical curves were used at the intersection of the profile lines and were calculated from the following formula:

$$D = \frac{(X + Y) \times T}{8}$$

Nomenclature

D is the offset from the point of intersection of the two grade lines; known as P.I.

X is the approach grade; Y the retreat grade. In the formula X + Y means the algebraic sum of the two components.

T is the total length of stations covered by the curve and is expressed in terms of stations. These tangents, (1/2 T) were assumed, the total amount of earthwork desired governing their length.

The offset to any point other than the P.I. was calculated by the following formula:

$$d' = D\frac{T^2}{Z^2}$$

Nomenclature:

Z is the distance measured horizontally and expressed in terms of stations, of the point of curvature, or point of tangencey as the case might be, to the desired point.

Generally, the tangents assumed are either 50, or 100 ft.

The offsets at the intersection of the transit lines were calculated from the formula:

$$E = T \tan. 1/4\ i.$$

T is the length of the tangent in feet and i the deflection angle at that point. Other points on these curves were calculated from the same formula that was used for vertical curves.

The earthwork was balanced within zones of 1000 feet in length so as to elimnate the posibilities of overhaul. An excess of 15% of the cut over the fill was necessary in oreder to proveide for shrinkage. Free haul is universally considered as 700 feet; and it was used as such in our calculations. Indefinite overhaul was calculated by the mass-diagram method. The cross-sections were plotted by means of the template and the areas, cut and fill, measured by

the planimeter. These areas are known as end areas. The sums of the successive end areas were established, which are in direct proportion to the final earthwork, or yardage. The balancing at the required places and the percentages excess were calculated from the end areas. Final earthwork was obtained by extension from standard tables. The results of all this work may be found on the earthwork computation sheets, herein.

Methods and Costs of Reconstruction of a Highway

Computation of vertical curve offsets.

Sta.	Tan(ft)	Solution of D, or d'.
2+50	50	(-.54-.60) 1/8=1.14/8=.14
6	50	(.54-3.00) 1/8=2.46/8=.31
9	100	(3.00-5.35) 2/8=2.35/4=.54
11	100	(5.35+.20) 2/8= 5.15/4=1.29
17	100	(.20 1.15) 2/8=1.35/4=.34
19	100	(1.15-5.00) 1/8=3.85/8=.48
21	50	(5.00-8.00) 1/8=3.00/8=.37
27+50	50	(8.00-4.00) 1/8=4.00/8=.50
30	50	(4.00+1.50) 1/8=2.50/8=.31
32	100	(1.50-0.00) 2/8=1.50/4=.40
40+50	50	(5.00-0.00) 1/8=5.00/8=.62
42+70	20	(0.00 8.70)×.05=.43
44	50	(8.70-5.00) 1/8=3.70/8=.47
51	100	(5.00-.50) 2/8=4.50/4=1.12
53	50	(0.50 0.40) 1/8=.90/8=.11
55	50	(0.40-1.70) 1/8=1.30/8=.16
57	50	(1.70 1.50) 1/8=3.20/8=.40

Methods and Costs of Reconstruction of a Highway

Sta.	Tan(ft)	Solution of D, or d'.
62	50	(1.50+0.40) 1/8 = 1.90/8 = .24
64	100	(0.40-1.60) 2/8 = 1.20/4 = .30
68	100	(1.60+3.60) 2/8 = 5.20/4 = 1.30
71	100	(3.60-2.80) 2/8 = 0.80/4 = .20
74	100	(2.80-0.10) 2/8 = 2.70/4 = .67
80	100	(0.10-6.40) 2/8 = 6.50/4 = 1.62
84	50	(6.40-0.00) 1/8 = 6.40/8 = .80
89	100	(0.00+1.70) 2/8 = 1.70/4 = .42
93	100	(1.70-1.40) 2/8 = 0.30/4 = .07
95	50	(1.40+2.40) 1/8 = 3.80/8 = .47
98	200	(2.40-0.10) 4/8 = 2.30/2 = 1.15
97	100	$d' = 1.15\ (1/2)^2 = 0.29$
99	100	$d' = 1.15\ (1/2)^2 = 0.29$

Methods and Costs of Reconstruction of a Highway

COSTS

Grading-

6682.2 yds. at \$.65 = \$4343.43

Overhaul-

15600 yds. hauled 100 ft. at \$.03 = \$468.00

Material for road surface-

Cost per yard (ave. haul 3 mi.) = \$1.30

Quarrying,spreading, etc. = \$.35

Total cost per cu. yd. = \$1.65

No. of cu.yards per 100 ft. = 19.8

No of stations 91 so the total number of cu. yds. of gravel used is 1801.8

Total cost of material is \$2972.97

Cost of rolling at \$100.00 per mile = \$200.00

Complete cost of pavement = \$3172.97

Earth Shoulders.

6 foot earth shoulders on each side of road.

Number of sq.yds. per station 133

Total for 91 stations=12133 sq. yds.

Cost at $.02 per sq. yd=$242.66

Spillway-

Yardage per station (concrete)=33.3

Total yardage for 11.5 stations=383.3

Cost of concrete at $1.40=$657.80

Rip-rap-470 yds. at $.25=$117.50

Tiling 1900 feet at $.038 = $72.20

Total cost of spillway=$847.50

Culverts-

Three culverts with a total of 41.1 cu. yds.

at a cost of $8.00 per cu. yd.= $328.80

Bridge Abutments-

174 cu. yds. of concrete per abutment.

Total cost (two abutments) at $6.00 per cu. yd.

(including raising of bridge)=$2064.00

All of the prices noted in our estimates were obtained from the County superintendent of Highways, Rock County, Wisconsin.

Methods and Costs of Reconstruction of a Highway

Summary of Estimate.

Grading	$4343.43
Overhaul	468.00
Gravel Pavement	3172.97
Earth Shoulders	242.66
Culverts	328.80
Spillway	847.50
Abutment	2064.00
Engineering	500.00
Total Cost	$12003.51

STA.	ELEV.	SECTION AREA CUT −	SECTION AREA FILL +	END AREA CUT −	END AREA FILL
0	105.0	4.5	5.1		
				10.3	1
1 −.60%	104.4	5.8	5.1		
				16.1	7
2 P.C.	103.8	10.3	2.6		
				–	
P.I. 2+50	(103.64) 103.5	–	–		
				17.3	7
3 P.T.	103.75	7.0	5.1		
				10.8	1.5
4 +.54%	104.30	3.8	10.3		
				10.2	12
5 P.C.	104.85	6.4	2.6		
				10.2	4.
6 P.I.	(105.71) 105.41	3.8	1.9		
				9.6	1
7 P.T.	108.40	5.8	16.0		
				3.3 8.9	2
8 P.C. +3.0%	111.40	6.4	12.8		
				21.8	1
9 P.I.	(114.94) 114.40	15.4	1.8		
				21.8	3
10 P.C. P.T.	119.75	6.4	1.2		
				15.9	1
11 P.I. +3.30%	(123.81) 125.10	9.5	10.2		
				9.5	2
12	125.3	0	19.2		
				9.0	2
13 +0.20%	125.5	9.0	1.2		
				20.5	6
14	125.7	11.5	5.1		
				19.3	1
15	125.9	7.8	6.4		
				20.6	1
16 P.C.	126.10	12.8	6.4		
				23.1	7
17 P.I.	(125.96) 126.30	10.3	1.2		
				21.8	3
18 P.T. −1.5%	125.15	11.5	2.6		
				24.3	1
19 P.I.	(123.52) 124.0	12.8	10.3		
				29.4	2
20 −5.0%	119.0	16.6	15.4		
				37.1	15
21 PI	(113.63) 114.0	20.5	0		
				167.5	
22	106.0	147.0	0		
				409.0	
23	98.0	262.0	0		
				462.0	
24	(88.81) 88.80	140.0	0		
				105.0	2
25 P.I.	82.0	0	20.8		
				0	6
26 −8.0%	74.0	0	39.2		
				0	5

STA.	ELEV.	SECTION AREA		END AREA		YARDAGE		REMARKS —
		CUT –	FILL +	CUT –	FILL +	CUT –	FILL +	
0	105.0	4.5	5.1					
				10.3	10.2	191	18.9	
1	104.4	5.8	5.1					
				16.1	7.7	29.8	14.3	
2 P.C.	103.8	10.3	2.6					
				—	—	—	—	
P.I. 2+50	(103.64) 103.5	—	—					
				17.3	7.7	32.0	17.3	
3 P.T.	103.75	7.0	5.1					
				10.8	15.4	20.0	28.5	
4	[illegible]	3.8	10.[illegible]					
				10.7	[illegible]	15.9	23.9	
5 P.C.	104.85	5.4	2.6					
				10.2	4.5	18.9	8.3	
6 P.I.	(105.41) 105.[illegible]	4.8	1.9					
				[illegible]	7.5	17.0	33.1	15%
7 P.T.	108.40	3.8	6.0					
				[illegible]	23.0	15.2	53.3	
8 P.C.	111.40	5.4	12.[illegible]					
				[illegible]	14.6	40.4	27.[illegible]	
9 P.I.	(114.34) 114.[illegible]	5.4	1.3					
				10.8	3.0	[illegible]	[illegible]	
10 P.T.	119.75	5.4	1.2					
				15.9	11.4	29.4	21.1	
11 P.I.	([illegible]) [illegible]	3.5	10.2					
				9.5	28.7	17.6	53.1	
12	[illegible]	0	10.2					
				9.0	20.4	16.7	37.8	
13	125.5	9.0	1.2					
				20.5	5.3	38.0	11.1	
14	125.7	11.5	5.1					
				19.3	11.5	[illegible]	21.3	
15	125.9	7.8	6.4					
				20.6	[illegible]	[illegible]	23.7	
16 P.C.	126.10	12.8	6.4					
				[illegible]	7.6	42.8	14.1	17%
17 P.I.	(125.90) 126.30	10.3	1.2					
				21.8	3.5	40.4	7.0	
18 P.T.	[illegible]	11.5	2.6					
				[illegible]	12.9	[illegible]	[illegible]	
19 P.I.	([illegible]) 124.[illegible]	2.8	10.3					
				29.4	25.7	54.4	47.6	
20	1190	16.6	15.4					
				37.1	15.4	68.7	28.5	
21 P.I.	(113.63) 114.0	20.5	0					
				167.5	0	310.2	0	
22	106.0	147.0	0					
				409.0	0	757.4	0	
23	98.0	262.0	0					
				462.0	0	856.0	0	
24	(83.91) 88.80	140.0	0					
				105.0	2.0	194.5	3.7	
25 P.I.	82.0	0	20.8					
				0	60.0	0	111.1	
26	74.0	0	39.2					
				0	54.0	0	100.0	

STA.	ELEV.	SECTION AREA CVT −	SECTION AREA FILL +	END AREA CVT −	END AREA FILL
27 P.I.	66.0.	0	14.8		
				32.0	1
28 −4.00%	(62.5) 60.0	32.0	0		
				35.5	1
29	56.0	3.5	14.4		
				10.5	1
30 P.I.	(52.31) 52.0	07.0	1.0		
				7.0	1
31 −1.5%	50.5	0	0		
				0	1
32 P.I.	(49.4) 49.0	0	14.4		
				0	2
33 0.00% CON. SPILLWAY	49.0	0	6.4		
				12.5	
34	49.0	12.5	0.8		
				12.5	2
35	49.0	0	24.0		
				0	
36	49.0	0	58.4		
				0	1
37	49.0	0	46.0		
				0	1
38	49.0	0	58.0		
				0	1
39	49.0	0	48.0		
				0	1
40	49.0	0	57.0		
				—	
P.I. 40+50	(49.62) 49.0	—	—		
				0	1
41 +5.0%	51.5	0	108.0		
				0	1
P.I. 41+50	54.0	0	136.0		
				0	
42	—	—	—		
				—	
42+50	54.0	0	70.5		
				0	
P.T. 42+70	(54.43) 54.0	—	—		
				—	
43 +8.7%	56.6	0	41.0		
				3.0	4
44	(64.83) 65.3	3.0	0		
				35.1	
45	70.3	5.1	5.7		
				9.1	2
46 +5.0%	75.3	4.0	24.0		
				11.7	4
47	80.3	7.7	25.5		
				12.2	
48	85.3	4.5	12.0		
				65.5	
49	90.3	61.0	0		
				87.0	
50 P.C.	95.3	2.6	0		
				29.8	

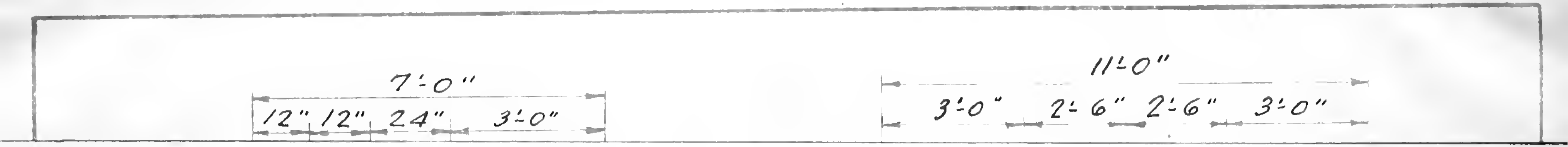
STA.	ELEV.	SECTION AREA		END AREA		YARDAGE		REMARKS —
		CUT −	FILL +	CUT −	FILL +	CUT −	FILL +	
27 P.I.	66.0.	0	14.8					
				32.0	14.8	59.3	27.4	
28 −4.00%	(62.5) 60.0	32.0	0					
				35.5	14.4	65.7	26.7	
29	56.0	3.5	14.4					
				10.5	14.4	19.4	26.7	
30 P.I.	(52.31) 52.0	07.0	1.0					
				7.0	18.0	13.0	33.3	
31 −1.5%	50.5	0	0					
				0	14.4	0	26.7	
32 P.I.	(49.4) 49.0	0	14.4					
				0	20.8	0	38.5	
33	49.0	0	6.4					
				12.5	7.2	23.1	13.1	
34	49.0	12.5	0.8					
				12.5	24.8	23.1	45.9	
35	49.0	0	24.0					
				0	82.4	0	152.6	
36 0.00% CON. SPILLWAY	49.0	0	58.4					
				0	104.4	0	193.3	
37	49.0	0	46.0					
				0	104.0	0	193.0	
38	49.0	0	58.0					
				0	106.0	0	196.3	
39	49.0	0	48.0					
				0	105.0	0	194.5	
40	49.0	0	57.0					
				—	—	—	—	
P.I. 40+50	(49.62) 49.0	—	—					
				0	16.50	0	30.56	
41 +5.00%	51.5	0	108.0					
				0	122.0	0	226.0	
P.I. 41+50	54.0	0	136.0					
				0	.0	0	.0	
42	—	—	—					
				—	—	—	—	CENTER OF BRIDGE
42+50	54.0	0	70.5					
				0	55.8	0	103.3	
P.T. 42+70	(54.43) 54.0	—	—					
				—	—	—	—	
43 +8.7%	56.6	0	41.0					
				3.0	41.0	55.6	75.9	
44	(64.83) 65.3	3.0	0					
				35.1	5.7	64.8	10.6	
45	70.3	5.1	5.7					
				9.1	29.7	16.9	55.6	
46 +5.0%	75.3	4.0	24.0					
				11.7	49.5	21.7	91.7	
47	80.3	7.7	25.5					
				12.2	37.5	22.6	69.5	
48	85.3	4.5	12.0					
				65.5	12.0	121.3	22.2	
49	90.3	61.0	0					
				87.0	0	161.1	0	
50 P.C.	95.3	2.6	0					
				29.8	11.5	55.2	21.3	23%

STA	ELEV.	SECTION AREA CUT −	SECTION AREA FILL +	END AR[EA] CUT −	F[ILL]
51 P.I.	(99.18) 100.3	3.8	11.5		
				10.8	
52 +0.5%	100.8	7.0	8.3		
				18.5	
53 P.I.	(101.19) 101.5	11.5	2.0		
				17.9	
54 −0.4%	100.9	6.4	7.0		
				12.2	
55 P.I.	(100.34) 100.5	5.8	16.0		
				7.7	
56 −1.7%	98.8	1.9	12.8		
				17.9	
57 P.I.	(97.51) 97.1	16.0	5.1		
				18.6	
58	98.6	2.6	11.0		
				14.1	
59	100.1	11.5	6.4		
				37.1	
60 +1.5%	101.6	25.6	0		
				35.9	
61	103.1	10.3	5.1		
				11.5	
62 P.I.	(104.36) 104.6	1.2	6.4		
				4.4	
63 −0.4%	104.2	3.2	7.7		
				19.2	
64 P.I.	(103.50) 103.8	16.0	1.2		
				16.6	
65	102.2	0.6	21.7		
				3.8	
66 −1.6%	100.6	3.2	12.8		
				12.2	
67	99.0	9.0	5.8		
				12.0	
68 P.I.	(98.7) 91.4	3.0	6.0		
				8.8	
69	101.0	5.8	22.4		
				21.8	
70 +3.6%	104.6	16.0	11.5		
				54.4	
71 P.I.	(108.0) 108.2	38.4	0		
				—	
72 +2.8%	111.0	—	—		
				93.2	
73 P.C.	113.8	71.8	24.3		
				11.0	
74	(115.93) 116.6	3.2	24.3		
				3.2	
75 P.T.	116.7	0	33.3		
				0	
76	116.8	0	32.0		
				0	
77 +0.1%	116.9	0	32.0		
				22.4	
78	117.0	22.4	0		
				111.9	

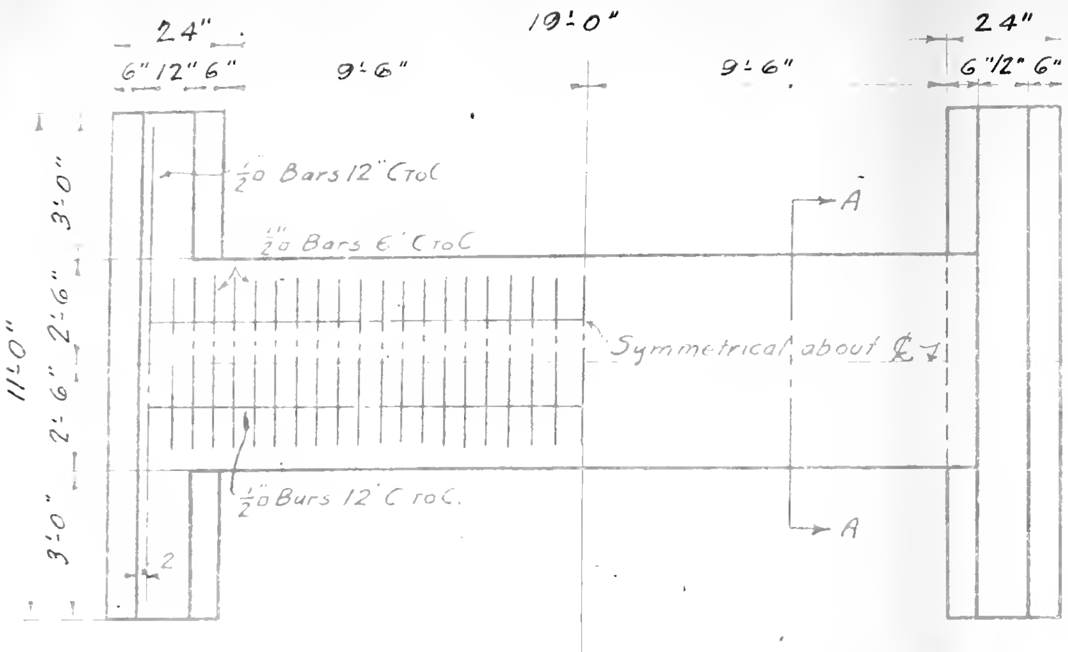
STA	ELEV.	SECTION AREA		END AREA		YARDAGE		REMARKS —
		CUT −	FILL +	CUT −	FILL +	CUT −	FILL +	
51 PI	(99.18) 100.3	3.8	11.5					
				10.8	5.0 14.8	20.0	9.3 27.4	10%
52	100.8	7.0	8.3					
				18.5	10.3	34.3	19.1	
53 PI	(101.19) 101.5	11.5	2.0					
				17.9	9.0	33.1	16.7	
54	100.9	6.4	7.0					
				12.2	23.0	22.6	42.6	
55 PI	(100.34) 100.5	5.8	16.0					
				7.7	28.8	14.3	53.3	
56	98.8	1.9	12.8					
				17.9	17.9	33.1	33.1	
57 PI	(97.51) 97.1	[illegible]	5.1					
				18.6	16.1	34.4	29.8	
58	98.6	2.6	11.0					
				14.1	17.4	26.1	32.2	
59	100.[illegible]	11.5	[illegible]					
				37.1	6.4	68.7	13.1	
60	101.6	25.6	0					
				22.0	5.1	56.5	9.4	
61	103.[illegible]	1.[illegible]	5.1					
				11.5	11.5	21.3	21.3	19%
62 PI	([illegible]) 104.[illegible]	[illegible]	6.[illegible]					
				4.4	14.1	8.1	26.1	
63	104.[illegible]	3.2	1.7					
				19.2	8.9	35.8	16.5	
64 PI	(103.5[illegible]) 103.[illegible]	6.0	[illegible].2					
				16.6	22.9	30.7	42.4	
65	102.[illegible]	0.6	21.1					
				3.3	34.5	7.0	63.9	
66	100.6	3.2	17.8					
				12.2	18.3	22.6	34.4	
67	99.0	3.0	5.8					
				12.0	11.8	22.2	21.9	
68 PI	(98.7) 31.4	3.0	6.0					
				8.8	28.4	16.3	52.6	
69	101.0	.58	22.4					
				21.8	33.9	40.4	62.8	
70	104.6	16.0	11.5					
				54.4	11.5	100.7	21.3	
71 PI	(108.0) 108.2	38.4	0					
				—	—	—	—	
72	111.0	—	—					
				93.2	3.0 18.6	172.6	5.6 34.4	15%
73	113.9	[illegible]1.8	[illegible]43					
				11.0	48.6	20.4	90.0	
74	(115.93) 116.0	3.2	24.3					
				3.2	57.6	5.9	106.6	
75 PI	[illegible]16.[illegible]	0	32.[illegible]					
				0	65.3	0	120.9	
76	116.9	0	32.0					
				0	64.0	0	118.5	
77	116.9	0	32.0					
				22.4	32.0	4.5	59.3	
78	117.0	22.4	0					
				111.9	0	207.2	0	

STA	ELEV.	SECTION AREA CUT -	SECTION AREA FILL +	END AREA CUT -	END AREA FILL +
79	117.1	89.5	0		
				106.8	[illegible]
80 P.I.	(115.50) 117.2	17.3	0		
				5.38	[illegible]
81	110.8	36.5	0		
6.4%				20.3 29.0	1.
82	104.4	12.8	1.2		
				10.8	49
83	98.0	0	48.6		
				0	73
84	(92.4) 91.6	0	25.0		
				0	7
85	91.6	0	48.5		
				9.0	10
86 0.00%	91.6	9.0	57.5		
				25.0	7
87	91.6	16.0	16.0		
				22.4	3
88	91.6	6.4	20.5		
				28.8	2
89 P.I.	(92.02) 91.6	22.4	3.2		
				46.7	3
90	93.3	24.3	0		
				69.3	[illegible]
91 +1.7%	95.0	45.0	0		
				135.0	[illegible]
92	96.7	90.0	0		
				115.0	[illegible]
93 P.I.	(98.33) 98.4	25.0	0		
				34.0	3.
94 +1.4%	99.8	9.0	3.2		
				54.0	3.
95 P.I.	(100.73) 101.7	45.0	0		
				50.8	1
96 -2.4%	98.8	5.8	13.0		
				10.9	4
97 P.I.	(96.69) 96.4	5.1	28.8		
				5.1	6
98 P.I.	(95.15) 94.0	0	24.4		
				0	6
99 P.I.	(94.19) 93.9	0	28.8		
				8.3	3
100	93.8	8.3	7.7		
				14.7	2
101 -0.1%	93.7	6.4	16.0		
				24.4	2
102	93.6	18.0	7.7		
				75.5	7
103	93.5	57.5	0		
				122.5	[illegible]
104	93.4	65.0	0		

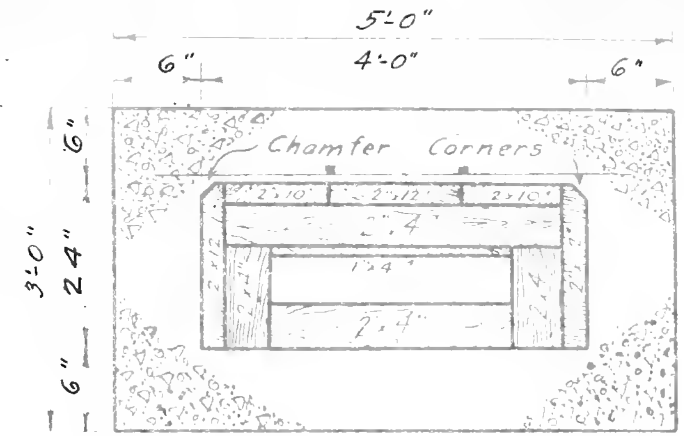
STA	ELEV.	SECTION AREA CUT −	SECTION AREA FILL +	END AREA CUT −	END AREA FILL +	YARDAGE CUT −	YARDAGE FILL +	REMARKS —
79	117.1	89.5	0					
				106.8	0	192.8	0	
80 P.I.	(115.50) 117.2	17.3	0					
				5.38	0	99.6	0	15%
81 6.4%	110.8	36.5	0					
				20.3 29.0	1.2	37.6 53.7	2.2	
82	104.4	12.8	1.2					
				10.8	49.8	23.7	92.2	
83	98.0	0	48.6					
				0	73.6	0	136.2	
84	(92.4) 91.6	0	25.0					
				0	73.5	0	136.1	
85	91.6	0	48.5					
				9.0	106.0	16.7	196.3	
86 0.00%	91.6	9.0	57.5					
				25.0	73.5	46.3	136.1	
87	91.6	16.0	16.0					
				22.4	36.5	41.5	67.6	
88	91.6	6.4	20.5					
				28.8	23.7	53.3	43.9	
89 P.I.	(92.02) 91.6	22.4	3.2					
				46.7	3.2	86.5	5.9	
90	93.3	24.3	0					
				69.3	0	128.3	0	
91 +1.7%	95.0	45.0	0					
				135.0	0	250.0	0	
92	96.7	90.0	0					
				115.0	0	213.0	0	16%
93 P.I.	(98.33) 98.4	25.0	0					
				34.0	3.2	63.0	5.9	18%
94 +1.4%	99.8	9.0	3.2					
				54.0	3.2	100.0	5.9	
95 P.I.	(100.73) 101.7	45.0	0					
				50.8	13.0	94.1	24.1	
96 −2.4%	98.8	5.8	13.0					
				10.9	41.8	20.2	77.4	
97 P.I.	(96.69) 96.4	5.1	28.8					
				5.1	67.2	9.3	124.4	
98 P.I.	(95.15) 94.0	0	24.4					
				0	67.2	0	124.4	
99 P.I.	(94.19) 93.9	0	28.8					
				8.3	36.5	15.4	67.6	
100	93.8	8.3	7.7					
				14.7	23.7	27.2	43.9	
101 −0.1%	93.7	6.4	16.0					
				24.4	23.7	45.2	43.9	
102	93.6	18.0	7.7					
				75.5	7.7	140.0	14.3	
103	93.5	57.5	0					
				122.5	0	226.9	0	32%
104	93.4	65.0	0					



7'-0"
12" 12" 24" 3'-0"
11'-0"
3'-0" 2'-6" 2'-6" 3'-0"



½ PLAN of REINFORCEMENT | ½ PLAN of FINISHED CULVERT



SECTION AA SHOWING FORMING

BILL OF MATERIAL

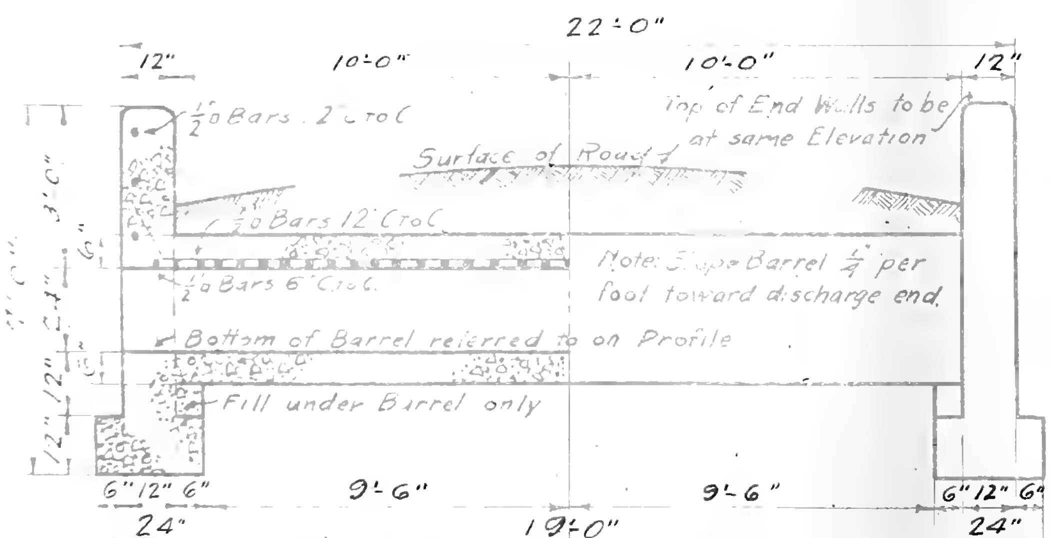
STEEL:

Bars ½"⌀ 12" C to C	long - A
Bars ½"⌀ 6" C to C	long - B
Bars ½"⌀ 12" C to C	long - C
Total Steel =	Pounds.

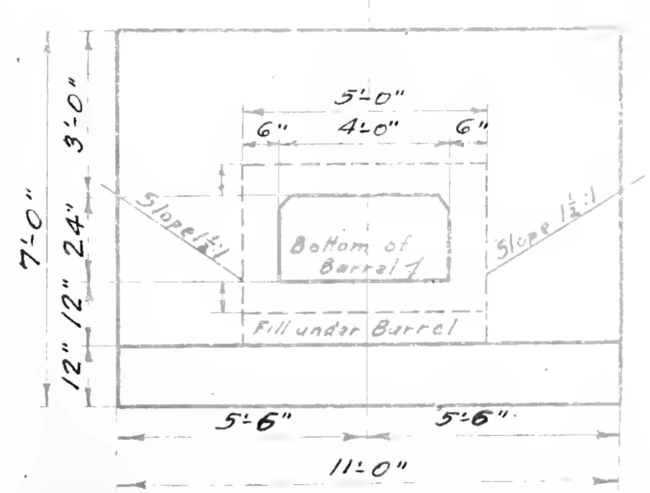
CONCRETE 1:2:4 Mix.

Two End Walls Contain....	6.9 Cu Yds.
Barrel 20'-0" long Contains.	7.9 Cu Yds.
Total Concrete....	14.8 Cu Yds.

CEMENT	14.1 Bbls.
SAND	4.2 Cu Yds.
STONE	8.4 Cu Yds.



½ TRANSVERSE SECTION on ℄ | ½ SIDE ELEVATION



END ELEVATION

CULVERT NO. 1

STATION NO. 2+50

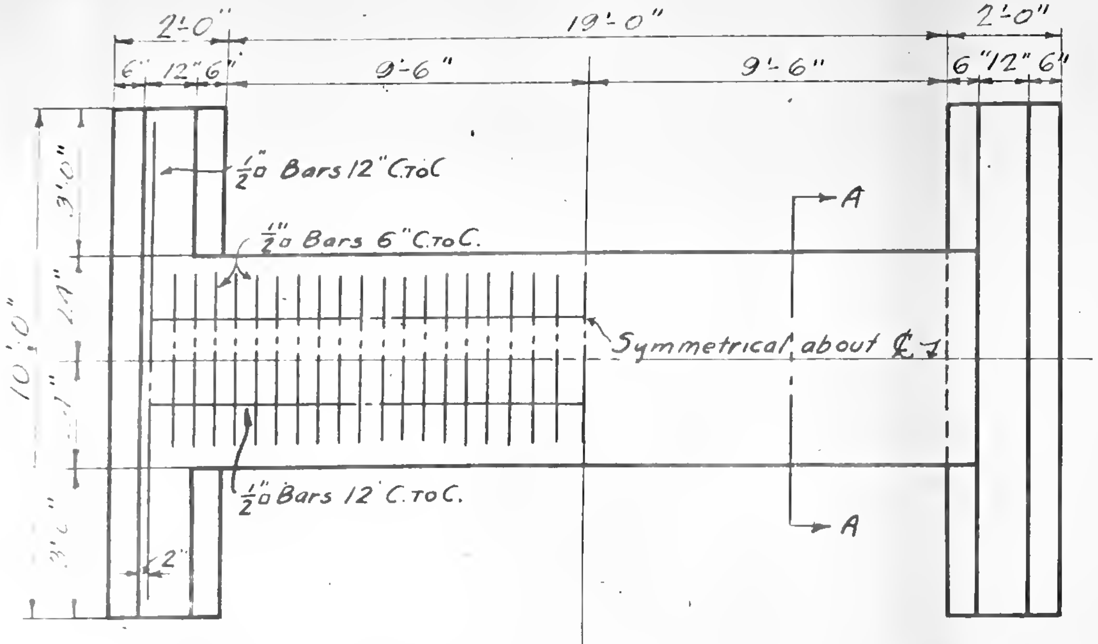
STANDARD 48"x24" REINFORCED CONCRETE CULVERT

THESIS

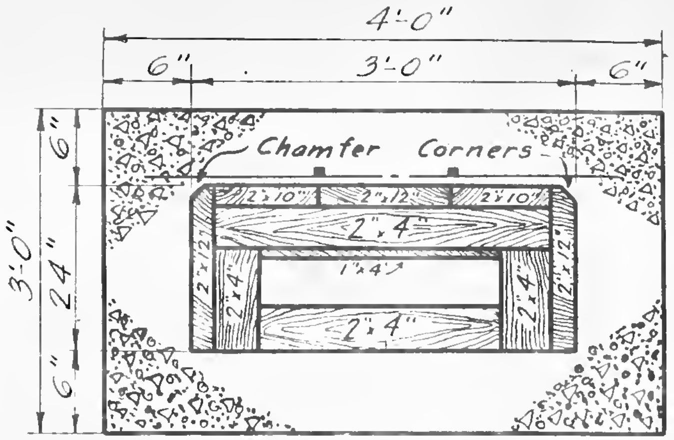
CHICAGO, ILL. MAY 1917

L. E. STARKEL, JAS. D. HARVEY, O. E. ANDRÉN


7'-0"
12"
12"
24"
3'-0"
6"
6"
10'-0"
3'-0"
24"
24"
3'-0"



½ PLAN of REINFORCEMENT | ½ PLAN of FINISHED CULVERT



SECTION AA Showing FORMING

BILL OF MATERIAL

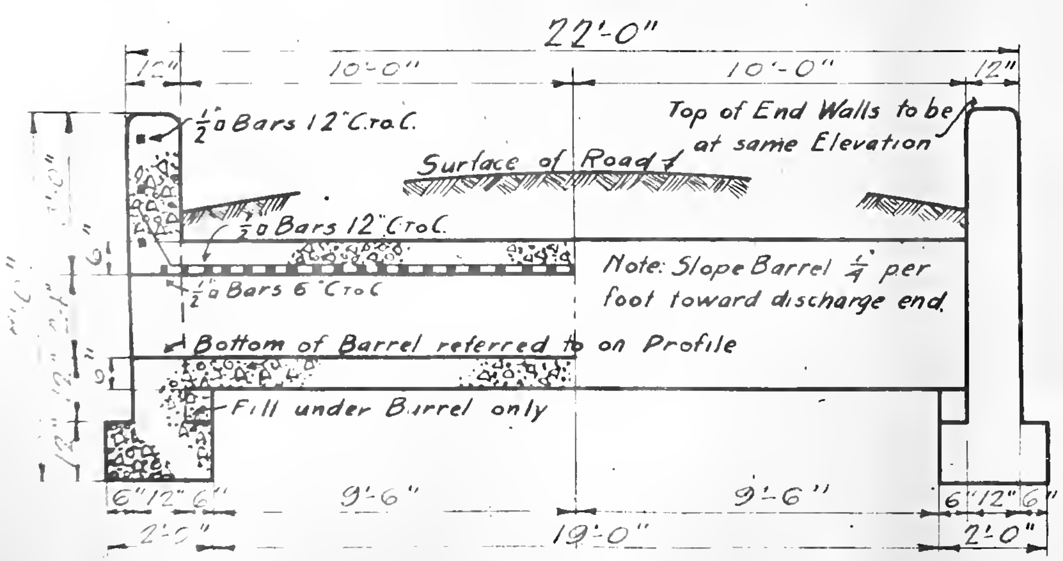
STEEL:

Bars ½" ⌀ 12" C. to C.	long - A
Bars ½" ⌀ 6" C. to C.	long - B
Bars ½" ⌀ 12" C. to C.	long - C
Total Steel =	Pounds.

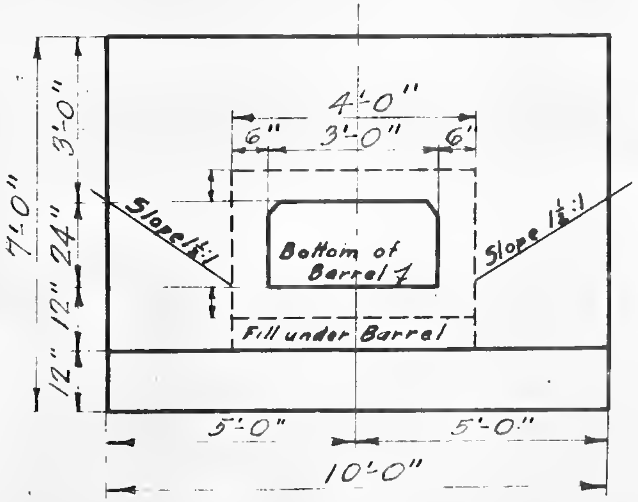
CONCRETE 1:2:4 MIX.

Two End Walls Contain.... 8.0 Cu. Yds.
Barrel 20'-0" long Contains. 5.6 Cu. Yds.
Total Concrete.....13.6 Cu. Yds.

CEMENT	13.0 Bbls.
SAND	3.9 Cu. Yds.
STONE	7.8 Cu. Yds.



½ TRANSVERSE SECTION on ℄ | ½ SIDE ELEVATION



END ELEVATION

CULVERT NO. 2

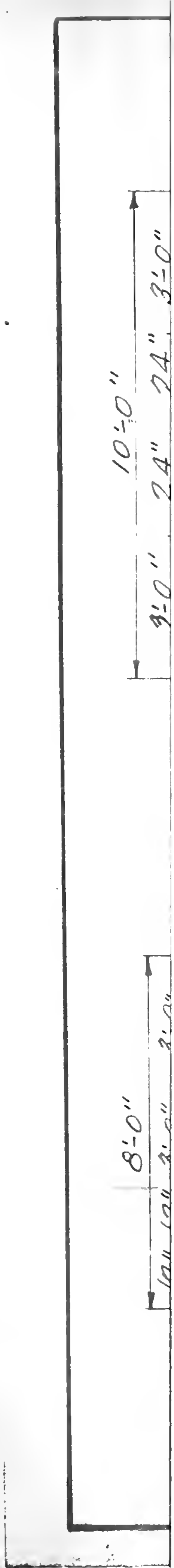
STATION NO. 69+60

STANDARD 36"x24" REINFORCED CONCRETE CULVERT

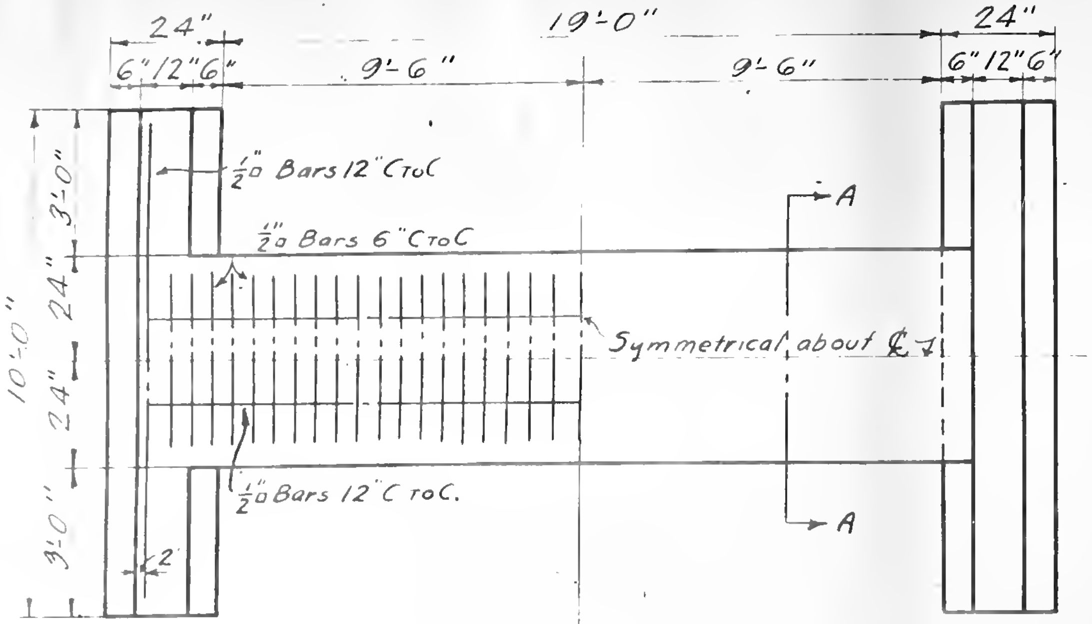
- THESIS -

CHICAGO, ILL. MAY 1917

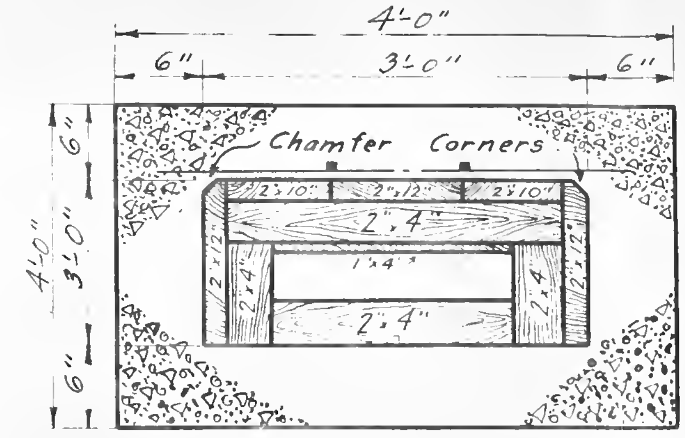
L. E. STARKEL, JAS. D. HARVEY, O. E. ANDRÉN



10'-0"
3'-0"
24"
24"
3'-0"
8'-0"



½ PLAN of REINFORCEMENT | ½ PLAN of FINISHED CULVERT



SECTION AA SHOWING FORMING

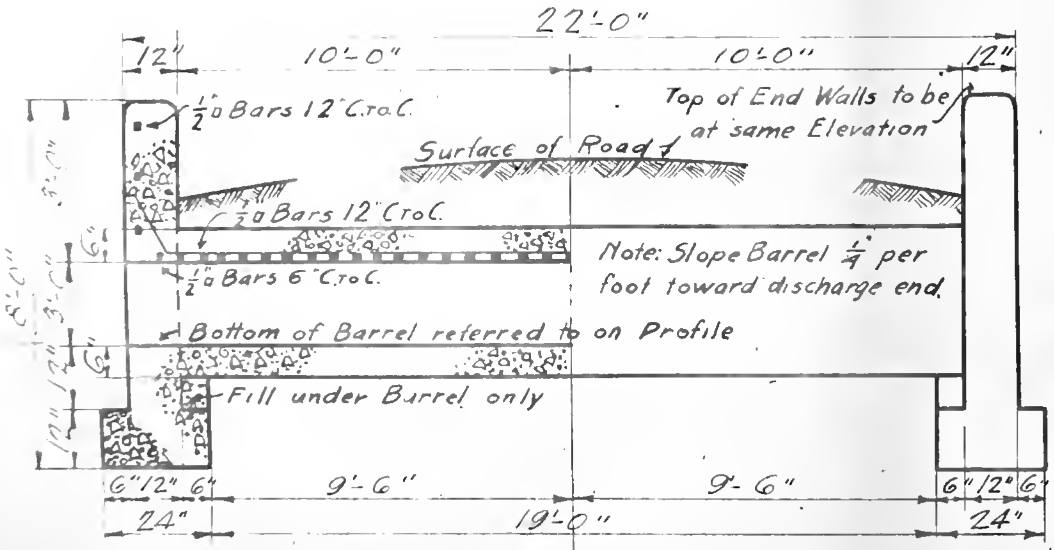
BILL OF MATERIAL

STEEL:

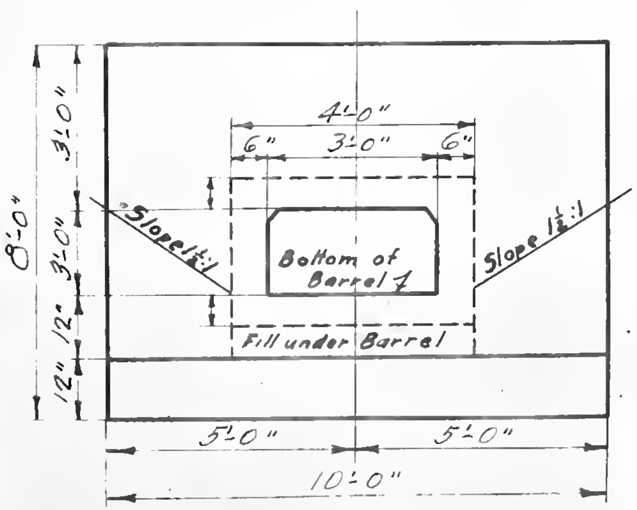
Bars ½" ⌀ 12" C. to C.	long - A	
Bars ½" ⌀ 6" C. to C.	long - B	
Bars ½" ⌀ 12" C. to C.	long - C	
Total Steel =		Pounds.

CONCRETE 1:2:4 MIX.

Two End Walls Contain....	10.0	Cu. Yds.
Barrel 20'-0" long Contains.	5.7	Cu. Yds.
Total Concrete.....	15.7	Cu. Yds.
CEMENT..........	15.0	Bbls.
SAND..............	4.5	Cu. Yds.
STONE.............	9.0	Cu. Yds.



½ TRANSVERSE SECTION on ℄ | ½ SIDE ELEVATION



END ELEVATION

CULVERT NO. 3

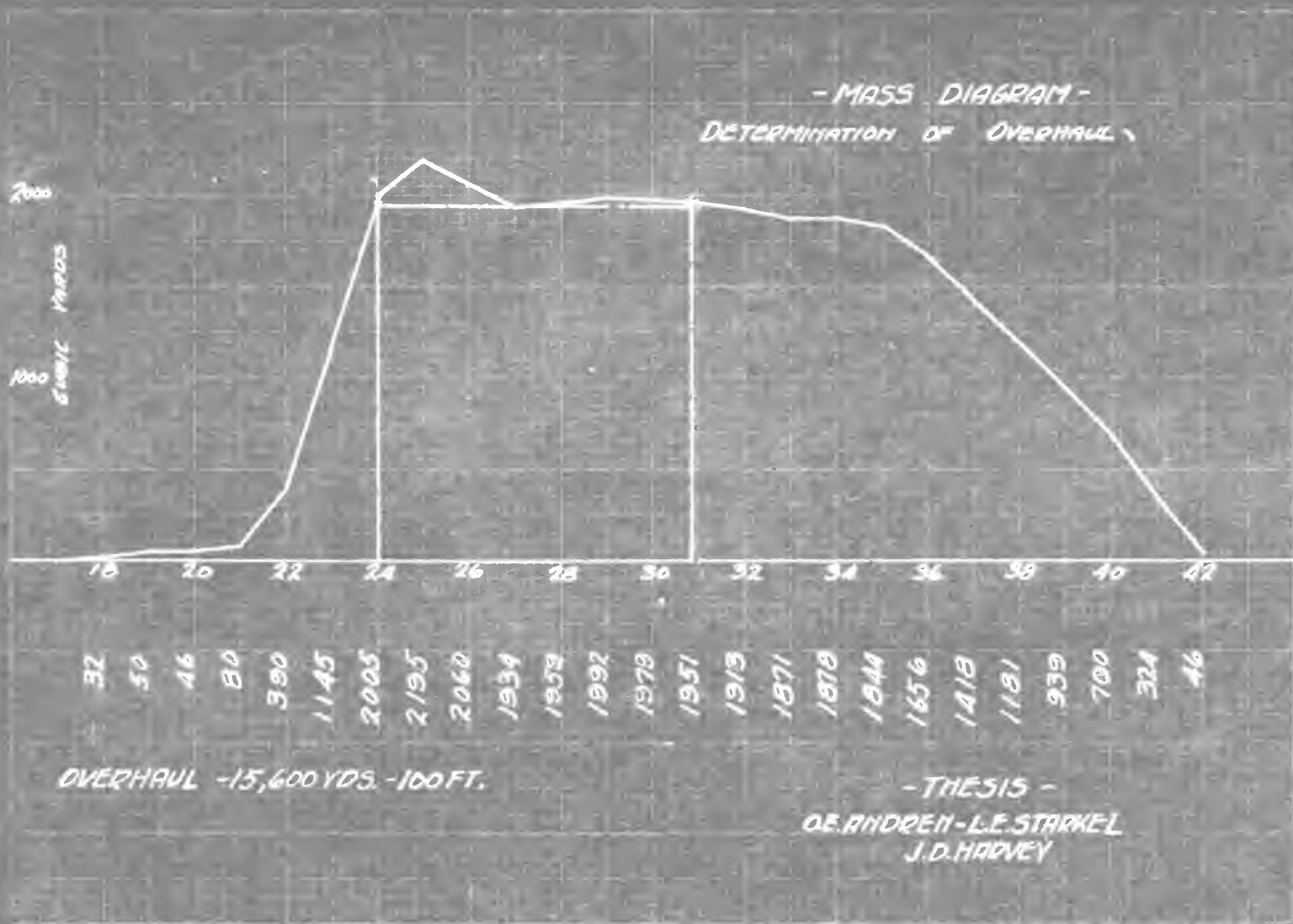
STATION NO. 85+30

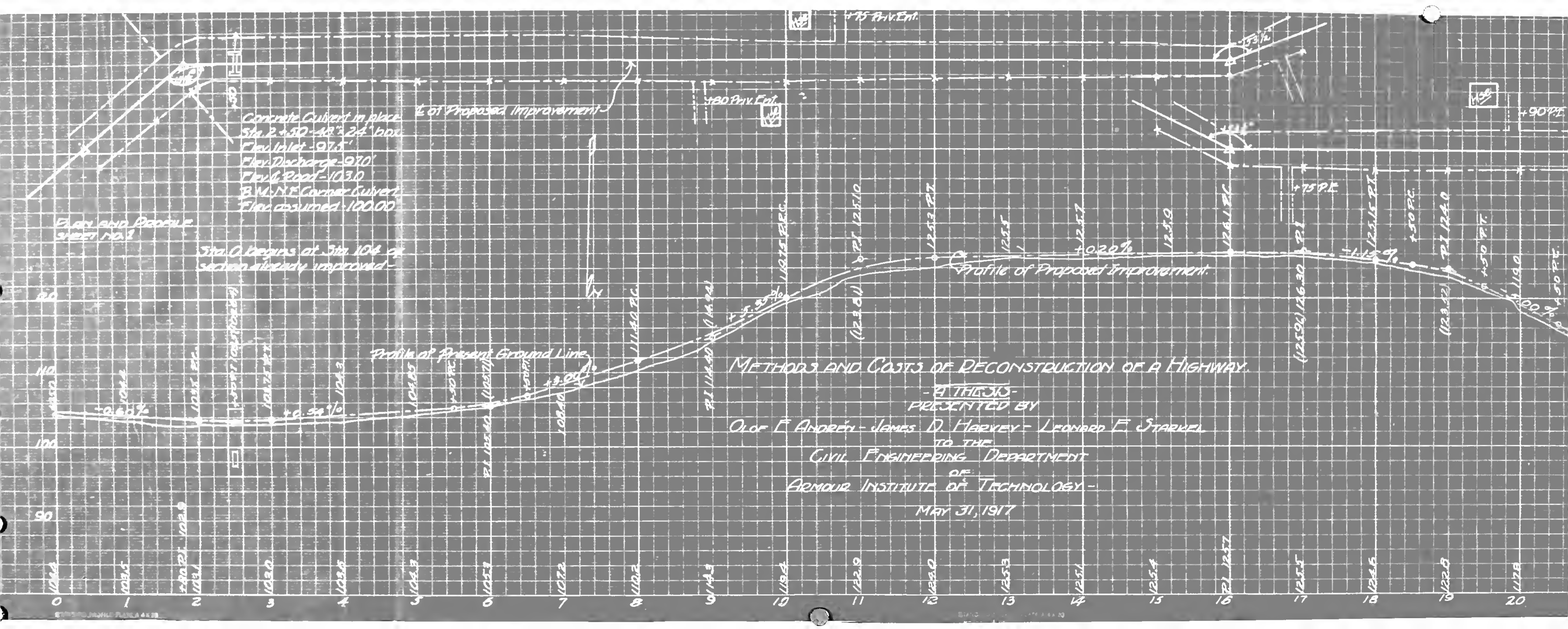
STANDARD 36" × 36" REINFORCED CONCRETE CULVERT

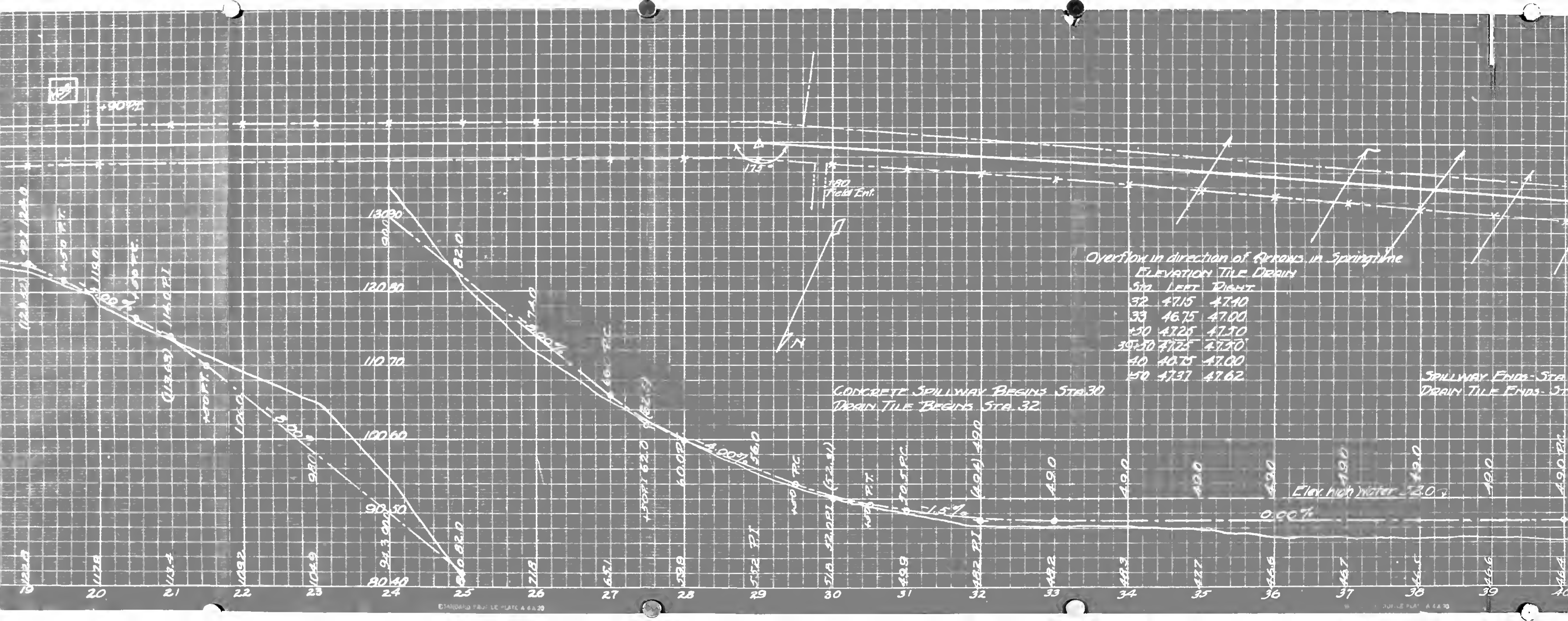
— THESIS —

CHICAGO, ILL. MAY 1917

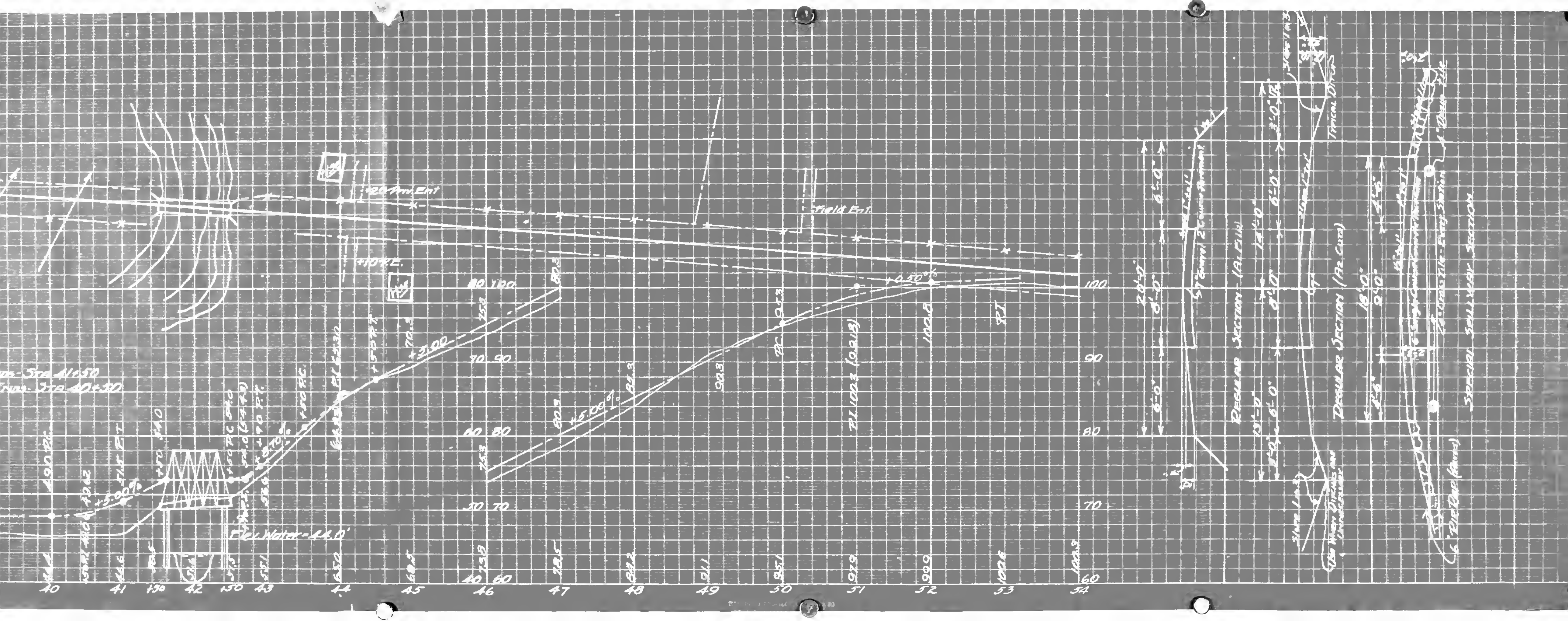
L. E. STARKEL, JAS. D. HARVEY, O. E. ANDRÉN


-MASS DIAGRAM-
DETERMINATION OF OVERHAUL.
2000
1000
CUBIC YARDS
18 20 22 24 26 28 30 32 34 36 38 40 42
32 50 46 80 390 1145 2005 2195 2060 1934 1958 1992 1979 1951 1913 1871 1878 1844 1656 1418 1181 939 700 324 46
OVERHAUL -15,600 YDS. -100 FT.
-THESIS-
O.E. ANDREN - L.E. STARKEL
J.D. HARVEY

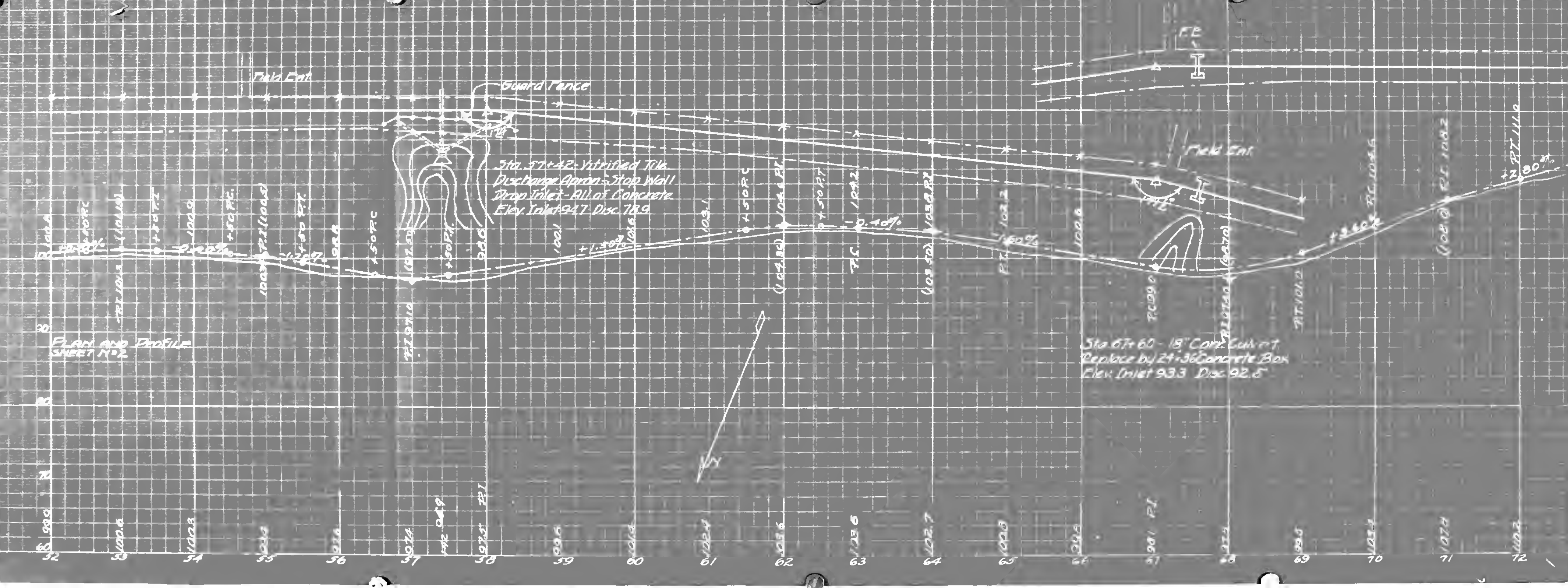

Concrete Culvert in place
Sta. 2+50 - 48" x 24" box
Elev. Inlet - 97.5'
Elev. Discharge - 97.0'
Elev. ℄ Road - 103.0
B.M. N.E. Corner Culvert
Elev. assumed - 100.00
℄ of Proposed Improvement
+80 Priv. Ent.
+75 Priv. Ent.
Plan and Profile
Sheet No. 1
Sta. 0 begins at Sta. 104 of section already improved -
Profile of Proposed Improvement.
Profile of Present Ground Line
-0.60%
+0.54%
+3.00%
+5.35%
+0.20%
-1.15%
METHODS AND COSTS OF RECONSTRUCTION OF A HIGHWAY.
- A THESIS -
PRESENTED BY
OLOF F. ANDRÉN - JAMES D. HARVEY - LEONARD E. STARKEL
TO THE
CIVIL ENGINEERING DEPARTMENT
OF
ARMOUR INSTITUTE OF TECHNOLOGY -
MAY 31, 1917
120
110
100
90
0
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
19
20



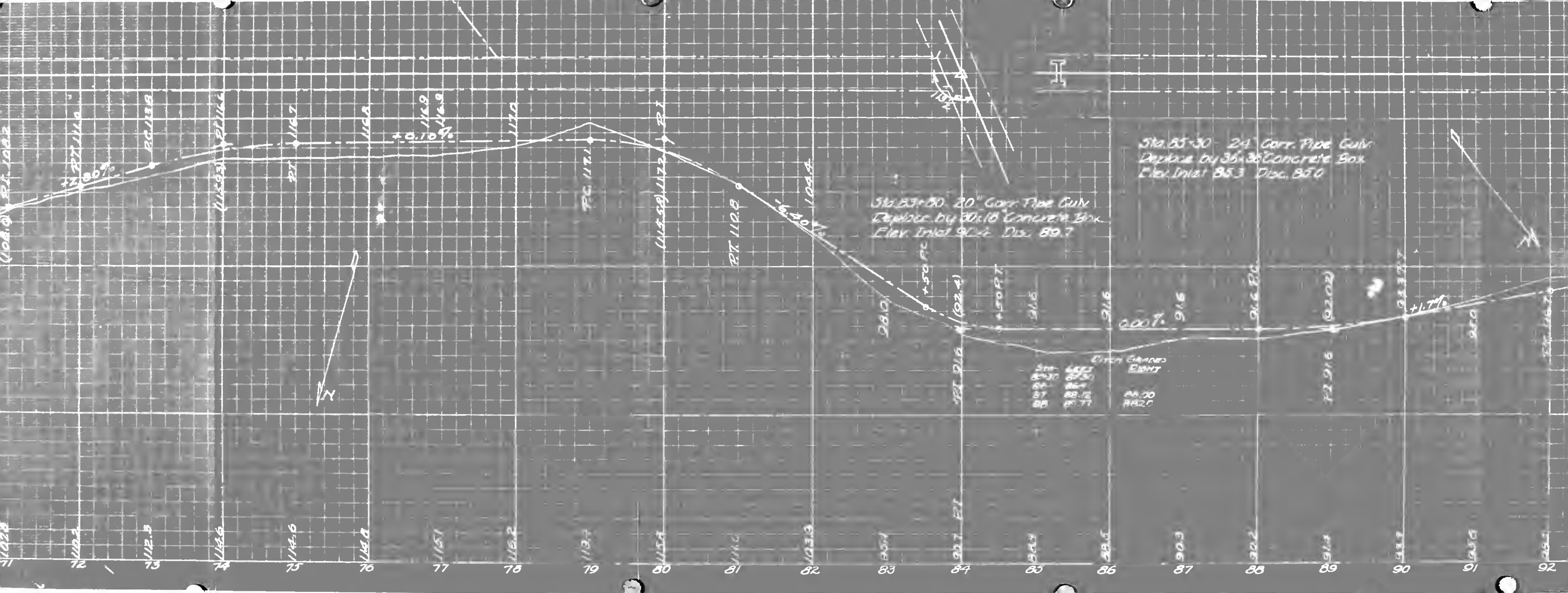
+90 P.I.
175°
+90
Field Ent.
N
Overflow in direction of Arrows in Springtime
ELEVATION TILE DRAIN
Sta Left Right
32 47.15 47.10
33 46.75 47.00
+50 47.25 47.50
39+50 47.25 47.50
40 46.75 47.00
+50 47.37 47.62
CONCRETE SPILLWAY BEGINS STA.30
DRAIN TILE BEGINS STA. 32
SPILLWAY ENDS-STA
DRAIN TILE ENDS-ST
Elev. high Water 52.0
0.00%
-1.5%
4.00%
8.00%
130 90
120 80
110 70
100 60
90 50
80 40
19
20
21
22
23
24
25
26
27
28
29
30
31
32
33
34
35
36
37
38
39
40
STANDARD PROFILE PLATE A 4 A 20



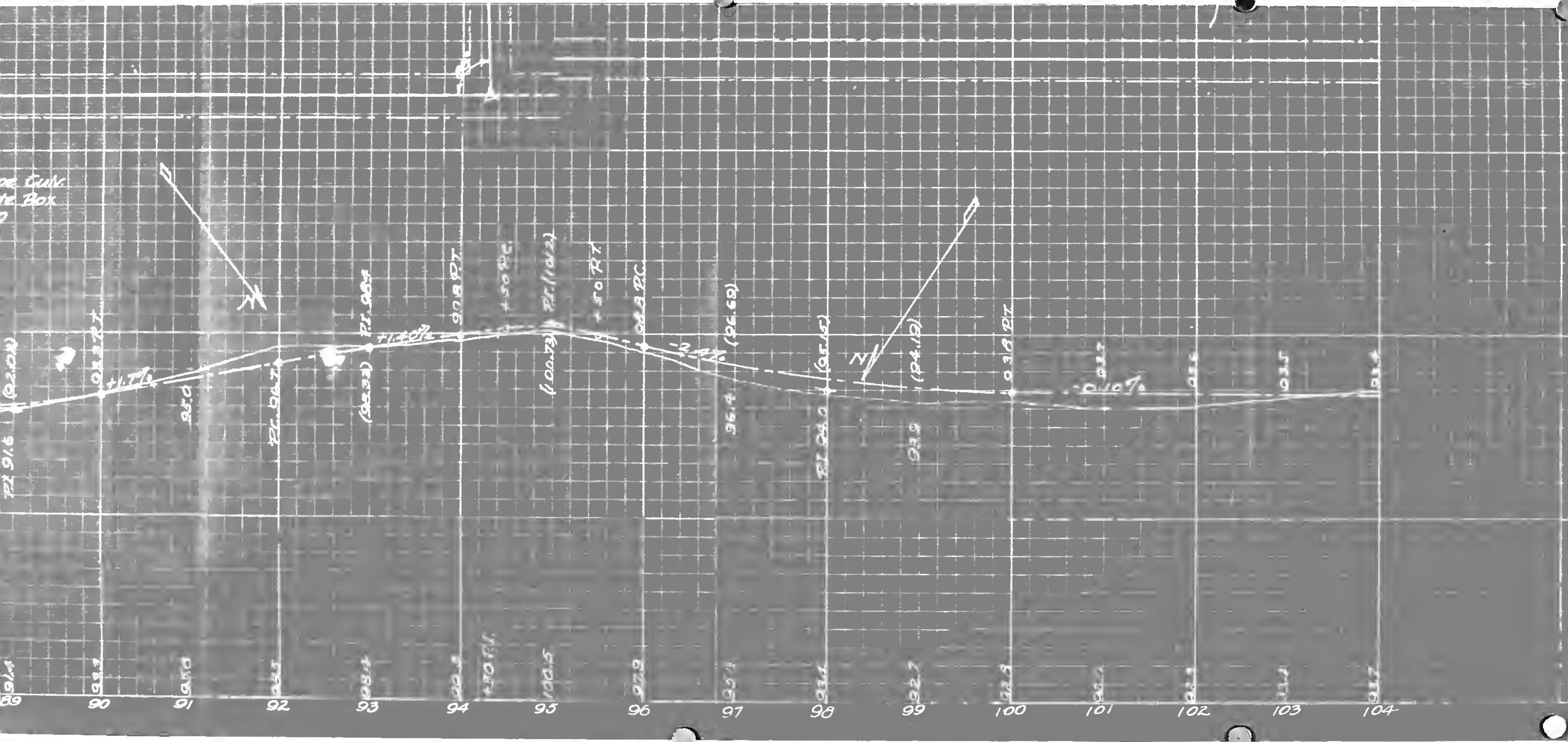
+20 Pvt. Ent.
Field Ent.
+10 P.E.
Elev. Water - 44.0'
+5.00%
+3.00
+0.50%
100
90
80
70
60
40
41
42
43
44
45
46
47
48
49
50
51
52
53
54
Regular Section - (At Fill)
Regular Section (At Cuts)
Special Spillway Section
Typical Ditch



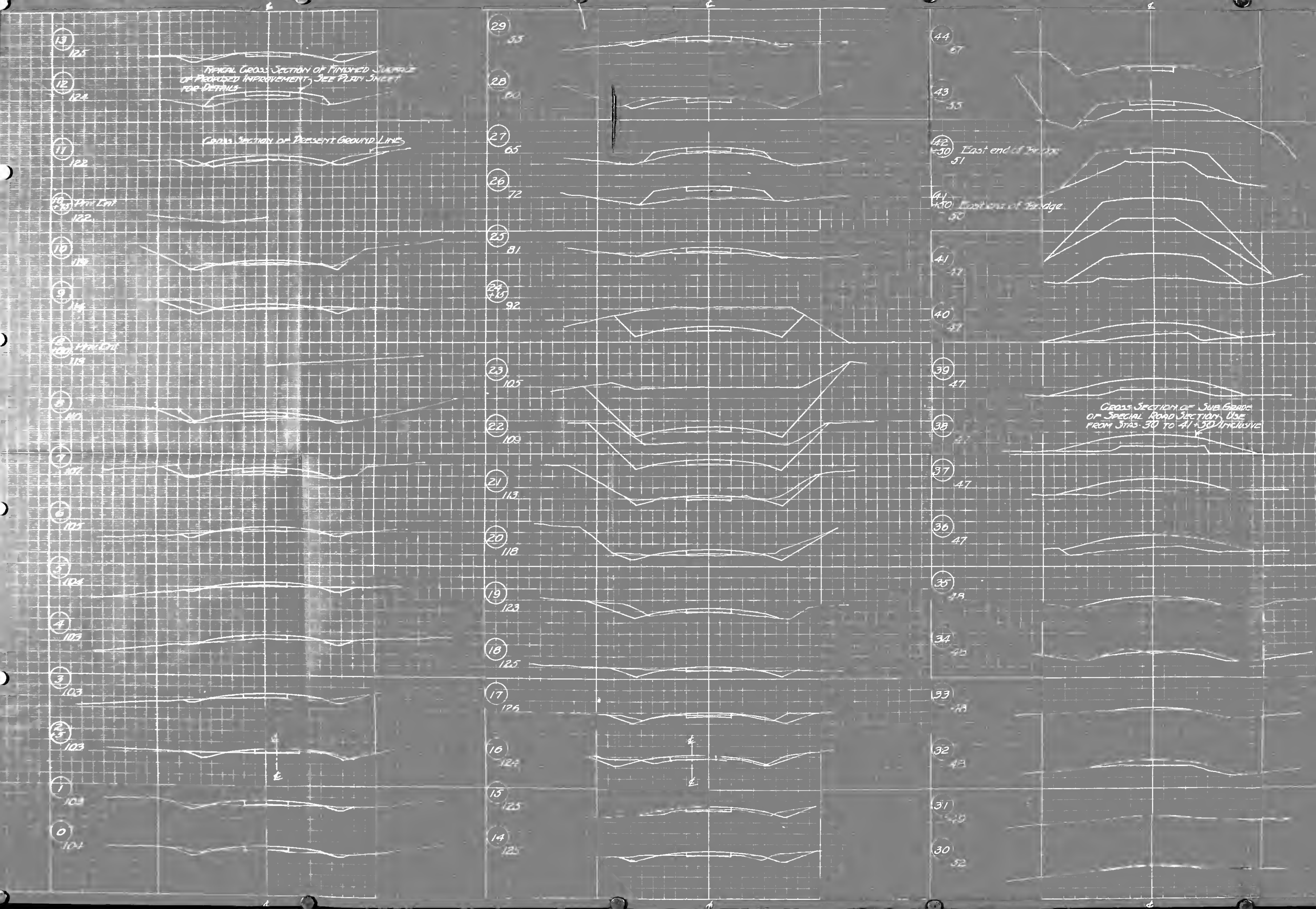
Field Ent.
Guard Fence
Sta. 57+42 - Vitrified Tile.
Discharge Apron - Stop Wall
Drop Inlet - All of Concrete
Elev. Inlet 94.7 Disc. 78.9
F.E.
Field Ent.
Sta. 67+60 - 18" Conc. Culvert
Replace by 24+36 Concrete Box
Elev. Inlet 93.3 Disc. 92.5
PLAN AND PROFILE
SHEET Nº2
32
33
34
55
56
57
58
59
60
61
62
63
64
65
66
67
68
69
70
71
72



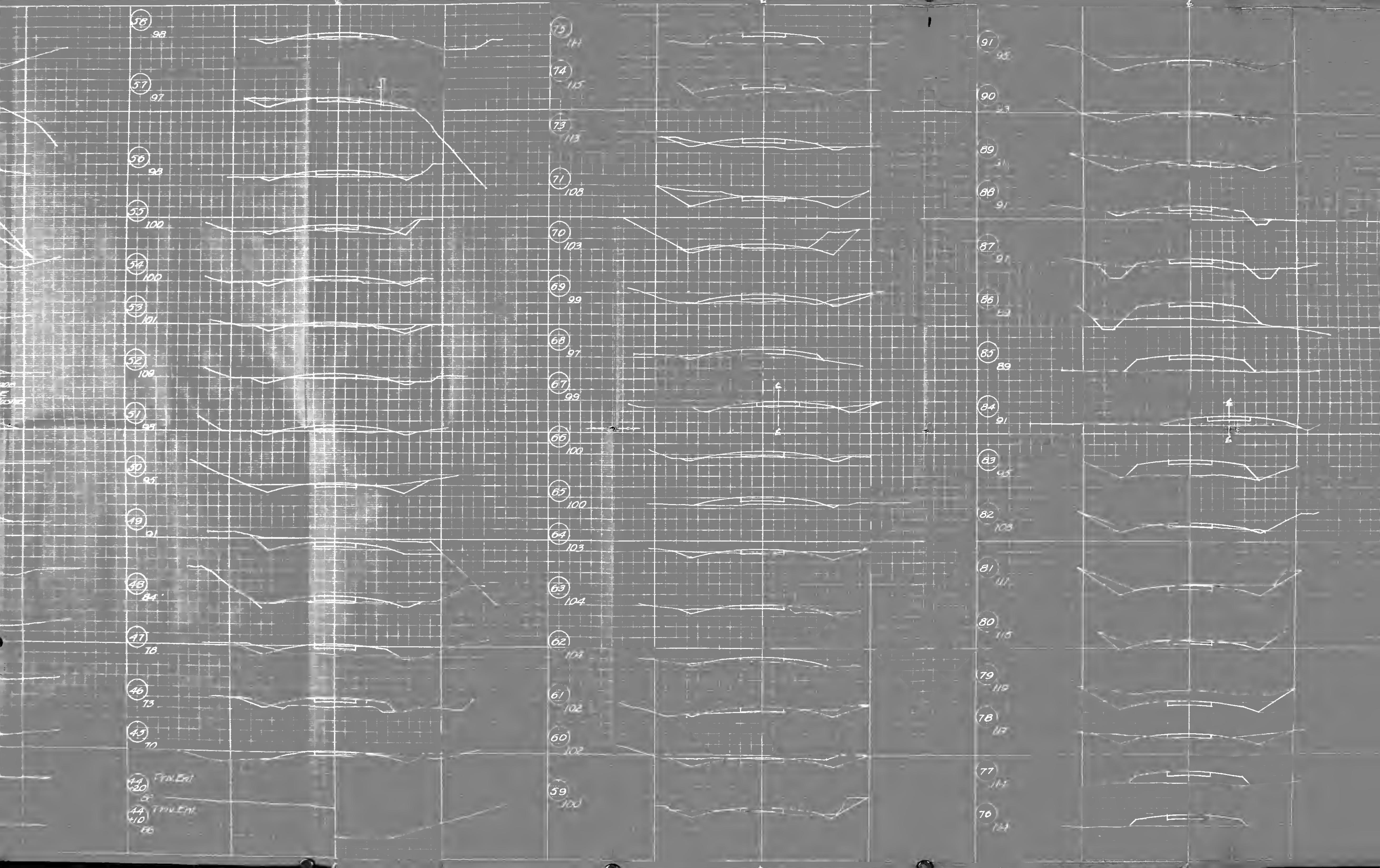
Sta. 83+80. 20" Corr. Pipe Culv.
Replace by 30x18 Concrete Box
Elev. Inlet 90.4 Disc. 89.7
Sta. 85+30 24" Corr. Pipe Culv.
Replace by 36x36 Concrete Box
Elev. Inlet 85.3 Disc. 85.0
+2.80%
+0.10%
-6.40%
0.00%
+1.7%
Ditch Graded
Right
71
72
73
74
75
76
77
78
79
80
81
82
83
84
85
86
87
88
89
90
91
92



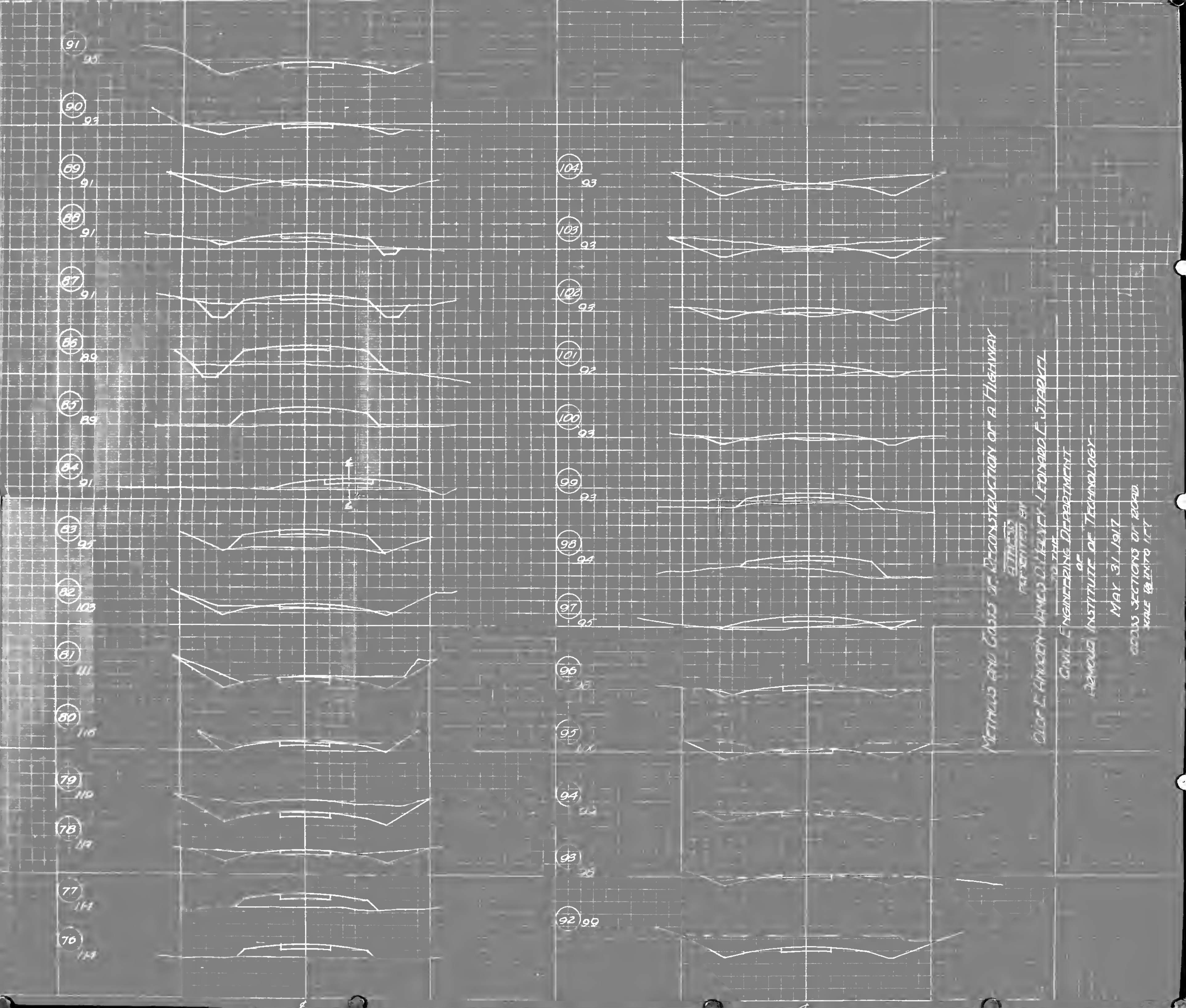
Box
P.I. 91.6
(92.08)
+1.17%
95.0
P.C. 96.7
(98.38)
+1.40%
98.8 P.T.
+50 P.C.
(100.73)
+50 P.T.
98.8 P.C.
-2.4%
(96.68)
96.4
(95.15)
N
(94.10)
93.9
93.8 P.T.
-0.10%
89
90
91
92
93
94
95
96
97
98
99
100
101
102
103
104



Typical Cross Section of Finished Surface of Proposed Improvement. See Plan Sheet for Details
Cross Section of Present Ground Line
East end of Bridge
Cross Section of Sub Grade of Special Road Section. Use from Stas. 30 to 41+50 Inclusive



58
98
57
97
56
98
55
100
54
100
53
101
52
51
50
95
49
91
48
84
47
78
46
73
45
70
44+20 Trns.Ent.
44+10 Trns.Ent.
75
114
74
115
73
113
71
108
70
103
69
99
68
97
67
99
66
100
65
100
64
103
63
104
62
104
61
102
60
102
59
100
91
90
89
88
91
87
91
86
85
89
84
91
83
82
108
81
80
116
79
119
78
77
76


METHODS AND COSTS OF RECONSTRUCTION OF A HIGHWAY
TO THE
CIVIL ENGINEERING DEPARTMENT
OF
INSTITUTE OF TECHNOLOGY -
MAY 31, 1917
SECTIONS OF ROAD